Heavy Metal Pollution in Indonesian Waters

Anita Yusfaddillah[1], *Riski* Dwi Saputri[1], *Tri Widya* Edelwis[2], and *Hilfi* Pardi[1*]

[1]Department of Chemistry Education, Faculty of Teacher Training and Education Raja Ali Haji Maritime University, Dompak, Tanjungpinang, Indonesia
[2]Department of Biology Education, Faculty of Teacher Training and Education Raja Ali Haji Maritime University, Dompak, Tanjungpinang, Indonesia

Abstract. Marine pollution, including heavy metals, is prevalent in Indonesian waters. Previous studies have found evidence of Pb, Cd, Hg, Al and Fe metal contamination in sediments and green mussels. This study used survey research. Heavy metal pollution is increasingly accumulating so that if it is not controlled it is feared that it will have an impact on public health, especially people who live around the coast. The research method was conducted using survey techniques. This study aims to estimate the burden of heavy metal pollution in the ocean. The research was conducted in 5 (five) areas of Indonesia, namely the East Coast of Sumatra, Winongo River in Yogyakarta, Semarang Bay, Bandengan Waters Kendal Central Java, and Ratai Bay Pasewaran Regency in areas with high human and heavy metal impacts. On average, the total results of heavy metal pollution exceed environmental quality standards. The situation in the 5 (five) research areas shows heavy metal pollution is very concerning because it is higher than the marine quality standard. The average concentrations of the measured elements in water were Al >Fe > Cu > Cd, with average values in descending order of 1.08 mg/L, 0.545 mg/L, 0.035 mg/L, and 0.005 mg/L, respectively. Environmental management should be implemented with the aim of reducing heavy metal pollution in Indonesian waters.

1 Introduction

Indonesia is the largest archipelago in the world, with approximately 17,500 islands and 108,000 km of coastline, 70% of its territory is covered by sea and freshwater consisting of open oceans, seas, beaches, estuaries, and bays. The abundance of marine natural resources, including diverse coral reef ecosystems, mangroves, and various species of fish and other marine life, gives Indonesia great potential in the marine and fisheries sector. However, despite this great potential, Indonesia's waters are also vulnerable to marine pollution, which can have serious impacts on the environment, economy and people's welfare [1–5].

* Corresponding author: hilfipardi@umrah.ac.id

Water pollution can come from a variety of human activities, such as industrial, agricultural and urban waste disposal, including solid, liquid, and gaseous wastes. Pollution can affect water quality, which can disrupt aquatic ecosystems and threaten the lives of aquatic life, including fish and other creatures [6–8]. Water pollution can also damage coral reef ecosystems, which are very important for the sustainability of the aquatic environment [9–13].

Heavy metals can bioaccumulate in aquatic species, which makes the contamination of marine and freshwater ecosystems with them a significant concern around the world. Due to their persistence, high toxicity, and bioaccumulation properties, heavy metals entering aquatic ecosystems, rivers, or oceans will be considered major pollutants. The metals Cd, Pb, Hg, Fe, and Al are threats that must be watched out for for the health of organisms, and their widespread distribution must be a matter of common concern. [14–18].

In Indonesian waters, there has been a significant increase in heavy metal pollution due to previous research indicating snails have concentrations of Pb (0.001-0.006 mg/L), Hg (0.001-0.005 mg/L), and Cd (0.005-0.03 mg/L) in them. Fresh water can be found in the Brantas River, Banten Province, Indonesia. The river and coast had Fe concentrations of 0.725 mg/L and 1.294 mg/L in plankton, respectively. Exceeding the quality standard threshold is causing the water quality standard for heavy metals to not be met.

2 Method

Survey research is the primary method of this research. This research was conducted in coastal areas of Indonesia such as the East Coast of Sumatra, Winongo River Yogyakarta, Ratai Bay Lampung, Bandengan Kendal Waters Central Java, and Semarang Bay. The object population is seawater in coastal residential locations associated with intensive human activities that affect heavy metals in coastal areas to provide a representation of heavy metal concentrations in various regions.

3 Result And Discussion

The role of water in life cannot be underestimated as it is a natural resource. Therefore, along with the demographic development and high industrial activity of the world community, this matter is directly proportional to the amount of waste produced. Water sources are gradually being polluted by waste, either garbage or industrial waste [4]. The health of aquatic biota is directly impacted by the exposure of heavy metals to aquatic ecosystems, leading to bioconcentration in various plant and animal tissues. Toxic heavy metals can be absorbed into human tissues through the food chain [19–24].

Heavy metals are metal elements with a specific gravity higher than 5 gr/cm3. There are several entry points and sources of heavy metals in rivers, both generated by natural and human activities. The health of aquatic biota is directly affected by the release of heavy metals into aquatic ecosystems, the release of heavy metals also causes bioconcentration in various plant and animal tissues. The food chain can lead to the absorption of toxic heavy metals into human body tissues [25–31].

Heavy metal pollution of aquatic ecosystems has become a significant issue for environmental health in recent decades. Residential, commercial, and other human activities discharge heavy metals, which is the main cause of heavy metal pollution in the

aquatic environment. The natural balance and biodiversity of the marine environment can be disrupted by heavy metal pollution, which can harm marine biota. The health of aquatic biota is directly affected by the release of heavy metals into aquatic ecosystems, the release of heavy metals also causes bioconcentration in various plant and animal tissues [24,32–34].
In the discussion, there are parameters in Indonesian waters that were tested in the study including:

Table 1. Water location and test parameters

No.	Location of Waters	Parameters
1.	East coast of Sumatera, Medan	Sea Water
2.	Winongo River, Yogyakarta	Freshwater and sediment
3.	Semarang Bay	Seawater, sediment and green mussels
4.	Bandengan Kendal Waters, Central Java	Water, sediment and soft tissue of feather clams
5.	Ratai Bay, Pesawaran Regency	River water and plankton

Heavy metals can be classified into essential and non-essential based on their toxicological properties. Certain essential heavy metals, such as Zn, Cu, Fe, Co, Mn, and Se, are required by living things in certain concentrations, but too much of them can be harmful. Non-essential heavy metals, however, are metals that have harmful qualities in small or large amounts and their potential health benefits are unclear. Hg, Cd, Pb, Cr, As, and Sn are some of these metals [35–39].

3.1 East Coast of Sumatera

Based on the table above Pb levels are far above the net worth, this is due to other reasons Lead is generated from industrial waste in the research environment, Pb is also sourced from the word sailing, namely fishing boats using gas fuel [15]. Lead is used in the battery industry, cables, coatings, and pesticides, such as your anti-detonation agent in gasoline, English welding composition or solder, as a pipe connection system. Here are the laboratory results of Pb and Cd metals on the East coast of Sumatera:

Table 2. Laboratory results of metals in Pb and Cd on the East Coast of Sumatra

Sample Location	Cd (NAB= 0.002 mg/l)	Pb (NAB= 0.005 mg/l)
Medan Labuhan	0.0042	0.52
Medan Marelan	0.0023	0.57
Medan Belawan	0.0029	0.52

3.2 Winongo River, Yogyakarta

The Winongo River had an average lead concentration of 0.02 to 0.69 mg/l. The WHO guidelines were clearly exceeded by all samples. The increase in Pb value in water is significantly influenced by these performances and the steel industry near the observation

point [4]. Lead from car fuels can be found in media on tires and clean organic residues, and life can be considered a pollutant in various activities. Heavy metal concentration in the Winongo River in Yogyakarta has resulted in the following.

Table 3. Results of heavy metal concentrations in Winongo River Yogyakarta

Regional Site Watershed	Cu (mg/L)	Cd (mg/L)	Al (mg/L)	Fe (mg/L)
Upstream	0.035	0.005	1.08	0.545
Middle River	0.025	0.00	1.7	1.445
Downstream	0.01	0.00	1.545	0.69

Table 4. River Qualitiy Standard PP RI No. 22 of 2021

No.	**Parameters**	**River Quality Standard PP RI No. 22 of 2021**	**Unit**	**Test Method**
1.	Pb	0.03	mg/l	SNI 6989.46:2009
2.	Cu	0.02	mg/l	SNI 6989.6:2009
3.	Cd	0.01	mg/l	SNI 06-6989.38:2005
4.	Al	0.2	mg/l	AAS
5.	Fe	0.3	mg/l	SNI 6989.84:2019

3.3 Semarang Bay

The results of this study show that the amount of heavy metals in the waters of Semarang Bay is slightly higher than the national quality standards issued by the Government Regulation of the Republic of Indonesia in the implementation of the Safety and Security plan. state restrictive environmental management. The maximum concentration (mg.L $^{-1}$) of Cd is up to 0.0334 and Pb is up to 0.0603 for aquatic organisms. This shows that Semarang Bay waters include metals contaminated with Cd and Pb . The following are the results of heavy metal concentrations in seawater in Semarang bay waters:

Table 5. Results of heavy metal concentrations in seawater in Semarang bay waters

Station Locations	Cd (mg/L)	Pb (mg/L)
Semarang	0.0251	0.0522
Demak	0.0334	0.0557
Kendal	0.0288	0.0603

Table 6. Results of heavy metal concentrations in sediments in Semarang bay waters

Station Locations	Cd (mg/L)	Pb (mg/L)
Semarang	0.0534	0.0229
Demak	0.0543	0.0358
Kendal	0.0459	0.052

Table 7. Results of heavy metal concentrations in green mussels in Semarang bay waters

Station Locations	Cd (mg/L)	Pb (mg/L)
Semarang	0.0403	0.0393
Demak	0.0403	0.0473
Kendal	0.0463	0.0485

3.4 Bandengan Kendal Waters, Central Java

The waters of Bandengan Kendal are part of the north coast of the Java Sea. Fishing ports, residential areas, and various companies surround the waters of Bandengan Kendal. Pollution of the maritime environment can result from this [6]. Animals that inhabit the marine environment, such as shellfish, will suffer from the development of this industry. The community's income depends on the sale of the shells [7]. Finding out how much lead is present in the soil, water, and soft tissue of feather shells is the purpose of this study. The study used the AAS (Atomic Absorption Spectrophotometer) analytical technique and was conducted in March and April 2022. In March and April 2022, the lead content of the mussels was analyzed, and the results showed that the lead content ranged from 0.840 to 4.093 mg/kg, 0.134-0.47 mg/l in water, and 5.251-12.303 mg/kg in sediment. Water from Bandengan Kendal has a lead content of 0.008 mg/l, exceeding the quality standard for lead heavy metal content according to the quality criteria of PP No.22 of 2021. The level of heavy metal lead in sediment in Bandengan Kendal Waters of Kendal Regency is still below the quality standard, according to ANZECC/ARMCANZ which states that the content of heavy metal lead in sediment should not exceed 50 mg/kg. Meanwhile, SNI 7387:2009 states that feather shells must meet the lead heavy metal quality standard of 1.5 mg/kg. Feather shells have more lead content than allowed by the quality standard. From sediment to water, the heavy metal concentration factor varied between 19.463 to 42.440. The range of bioconcentration factors (BCF) between feather shells and water was 5.021-11.932, while the range between feather shells and sediment was 0.159-0.404.

3.5 Bandengan Kendal Waters, Central Java

Eight observation stations were used to collect water and plankton samples; four of them were around Bunut Seberang village, Way Urang village, Kephong Jaya village, and Sanggi Pematang Awi village, and the other four were between the river mouth and Teluk beach. Station A, the initial station, was located on the riverbank where ASGM activities took

place. The next station, station C, was taken from station A at a distance of approximately 500 m, but stations C and D were taken much further away.

Table 8. Heavy metal concentrations in Ratai Bay Lampung

Heavy Metals	Cd (mg/L)	Fe (mg/L)	Cr (mg/L)	Zn (mg/L)
A [Bunut Seberang Village (Way Ratai River)]	-	0.547	-	0.1003
B (Kepong Jaya Village)	-	0.7903	-	0.0329
C (Way Urang Village)	0.0064	0.6369	-	0.0506
D (Way Ratai stream at Sanggi Desa, Pematang Awi)	0.0077	0.3209	-	0.0543
E (Ratai Muara Road)	0.0145	0.1861	-	0.0935
F (Teluk Ratai Beach)	0.0082	0.1962	-	0.0585
G (Teluk Ratai Beach	0.0132	0.0104	-	0.0683
H (Teluk Ratai Beach	0.0088	1.313	-	0.0562

The results obtained show that the most heavy metal content is found in plankton, with concentrations in the form of Fe and Zn. Cd and Cr are not present in the plankton at the research location, but they are present in the waters. The quality standards of freshwater have been exceeded due to the presence of heavy metals such as Cd and Fe. For coastal waters, the concentrations of Cd, Fe, and Zn have also exceeded freshwater quality standards. It is evident that Way Ratai waters are polluted, and this may be due to different resources, city activities, or other activities. [5].

4 Conclusion

The situation on the east coast of Sumatra shows that Pb and Cd pollution is very concerning because it is higher than the marine quality standard based on Law No. 51/2004 of the Ministry of Health. The environment is 0.005 mg/l. The results of research in Winongo River, Yogyakarta showed that heavy metals (Pb, Cu, Cd, Al and Fe) in river water exceeded the limit according to WHO class II water quality standards in Indonesia. The spatial distribution of heavy metals in the water shows that the concentration of heavy metals in the middle of the river is higher than elsewhere, and pollution comes from urban areas, highways, metal factories and fisheries. And research has been conducted on heavy metal accumulation and environmental hazards in Semarang Bay waters. Concentrations in water were higher than in sediment and green mussel eggs. Cd concentrations were higher in sediment than in sediment. The diversity of machines that provide these machines causes environmental diversity, and human activities can exacerbate the risks to the environment of Semarang Bay.

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